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A NEW AVIATION FOR HEAVY TRANSPORT

Jean Bertin

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16. Abstract

Air freight is handled today by aircraft whose performance is designed for passenger service. Speed increase has led to nonstop flights at high altitudes, thus requiring a fuel load greater than the actual payload. For freight, however, aircraft flying at 200 knots would be perfectly suitable. They could fly at low altitudes, stop on the way and carry a payload much greater that fuel capacity. To be economical, such aircraft must be large (1,000 tons or more), and air-cushion landing will become a necessity. Numerous tests conducted on the Bertin air-cushion for air drops have been quite encouraging. Transfer of this technique to aircraft landing does not create particularly difficult problems.

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A NEW AVIATION FOR HEAVY TRANSPORT /2*

Jean Bertin

A certain number of studies conducted for a number of years at Societe Bertin & Cie. by a team consisting particularly of Messrs. Perineau, Cayla, Guienne and Collard have lead the persons responsible therefor to the conviction that a new form of commercial aviation for the carriage of goods will be born within the next few years. In order to arrive at this conclusion, it was necessary for a series of technical and economic factors to be combined thus making reasonably clear what had been merely a diffuse intuition for a long time.

The first element in the evolution originated in the following basic remark: virtually all of the air freight is transported nowadays in aircraft designed and built to accommodate passenegers. As flight speed is the main parameter in this respect, builders have always sought to increase it. Flight altitudes have thus increased at the same time, since high speeds are only conceivable in low atmospheric density by virtue of the very harsh and common law that flying power is proportional to the cube of speed.

If a B 707 were to attain its present cruising speed at the same altitude as a DC 4, the ratio of the effective specific powers should be in the vicinity of 20.

The quasi parallelism of flight speeds and altitudes is a matter of history, and we can roughly distinguish four main stages:

-- 200/300 kph at an altitude of 1,000 to 2,000 m with non-pressurized aircraft prior to 1939;

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* Numbers in the margin indicate pagination in the foreign text.

-- 400/500 kph, at an altitude of 4,000 to 5,000 m with pressurized aircraft of the 1945 to 1956 vintage using piston engines with turbo-compressors;

-- 700/900 kph, from 7,000 to 12,000 m, for subsonic jets;

-- And finally, more than 2,000 kph, above 15,000 m, for the Concorde.

Disregarding the Concorde, which is still somewhat of a special case, we are essentially in the era of subsonic jets capable of carrying 100 to 400 passengers at cruising speeds in the vicinity of 900 kph over distances ranging up to about 10,000 km.

It seemed natural to use these same aircraft to carry cargo, since there is a category of products whose value per unit of weight is such that the saving in interest on the moneys invested as a result of the reduction in tie-up time during transportation (or as a function of a number of other considerations that are weel known today: reduction of inventory, speed of delivery, etc.) more than compensate for the higher cost of this type of carriage as compared to carriage by sea.

Progress in this respect has been quite substantial: on the one hand, the annual rate of increase of air freight is very high throughout the world (from 10 to 25%, depending on the country); on the other hand, the new aircraft recently put into service can carry from 40 to 100 tons across the Atlantic.

From this simple standpoint, the situation regarding carriage of goods by air might appear to be favorable for a number of reasons, development speed, use of materials designed and depreciated (this is less certain) in connection with other uses, i.e., passenger service.

Reality proves to be much less satisfactory when facts are studied more closely. The trend to high flight speeds and therefore to high flight altitudes leads to a definite corollary: the present jet is virtually condemned to non-stop flight. Everything leads in this direction. If it is necessary to stop en route, it will be necessary to take a whole series of unfortunate consequences into account:

-- The increase in transport time, which might range from 25 to 100%, depending on the cases and on the number of intermediate stops;

-- The increase of relative crew expenses, an important factor if a basic ton/kilometer cost price is involved;

-- The increase of the depreciation expense of the material (less kilometer tons produced during the life of the aircraft, and even a reduction thereof by a repetition of the number of takeoffs and landings);

-- The increase of fuel consumption due to the fact that the engines are not adapted to intermediate-altitude flight and to the possible holding flights;

-- The increase of expensive airport fees, since the use of long and high-quality runways are involved due to the design of the aircraft themselves;

-- And so on.

We now arrive at the key point of the problem. To say that a nonstop flight is involved means that the aircraft must carry all of its fuel. It is now easy to show what this means. In a transatlantic flight, a 707 carries 22 tons of payload and 46 tons of fuel; a Series 62 DC 8 carries 30 tons of payload and 75 tons of fuel; a 747 carries 50 tons of payload and 100 tons of fuel. Bluntly speaking, it is not the carriage of goods that is involved, but rather the transport of petroleum. On the average, the payload actually amounts to no more than 50% of the fuel that must be carried. These are not cargo aircraft but flying tankers.

It is evident that this ridiculous situation, although it may be momentarily acceptable for certain categories of special high-priced goods, can not last. The first idea that might come to mind is the matter of refueling in flight. But this does not seem to be commercially feasible, either from the standpoint of cost or as a result of the complexity of the system, which requires back-up aircraft and crews, without mentioning the intrinsic procedural difficulties. The military themselves resort to this only as a function of certain exceptional criteria (the need to maintain major weapons in the air, nuclear fighters and bombers, for example).

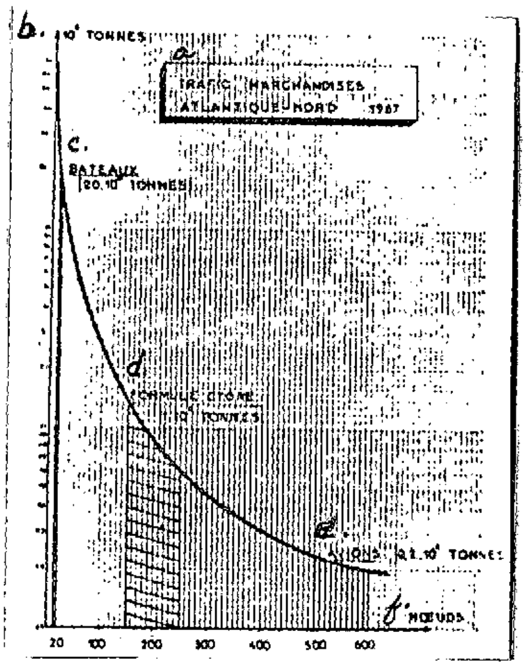

Figure 0

Key: (a) North Atlantic Traffic of Goods -- 1967
(b) 10^6 tons
(c) Vessel [$20 \cdot 10^6$ tons]
(d) Cygne formula [$1 \cdot 10^6$ tons]
(e) Aircraft [$0.2 \cdot 10^6$ tons]
(f) Knots

There is another solution as we see it. One of the first observations that led us in that direction was the following: while high speeds are one of the basic criteria for the transport of persons, this is not true in the case of goods. The major portion of goods do not have to travel at 1,000 or 2,000 kph. Moreover, if we consider the situation prevailing over the Atlantic, where the carrier can only choose between a 12- to 15-knot vessel and a 600-knot cargo jet, i.e., about 40 times faster, it reveals two things: the first is that the focus of interest in the case of goods lies well within areas of moderate speed; the second is that while there are goods for which transport at 600 knots is economically justified, there is a non-negligible amount for which speeds between 15 and 600 knots would be in order. The simple law of probabilities points to this! By analogy with other fields, we have thought that a speed of about 200 knots (280 to 360 kph)would probably be valid (Fig. 0).

Now, when we direct our attention more particularly to air transport, we realize that this area of speed that permits crossing the Atlantice in about twenty hours, for example, applies to a particularly interesting type of aircraft. It is actually an extremely easy speed flight area, where everything is known and where technology is very simple. But it is also an area that does not require high-altitude flight and which, moreover, permits the selection of any altitude between zero and 3,000 meters. At this time, landing (or alighting in water) en route becomes economically feasible and desirable in the measure in which, by providing for refueling, it completely alters the economic aspect of transport by completely inverting the value of the effective load/fuel /4 ratio. The aircraft ceases to be the flying tanker we mentioned to become a cargo aircraft in the true sense of the word, since the transported cargo is the preponderant element insofar as weight is concerned.

If we consider a specialized aircraft for the carriage of goods, it becomes immediately necessary to consider the problem of dimensions and unit tonnage. This is an important second factor in our reflections. It is actually a certainty, considering what happens in other fields, that the cargo aircraft can be very large. Since the frequency of departures does not play the same role as in the case of passengers, flights can be spaced more and loads concentrated, thus reducing the incidence of personnel and stopover expenses. In conclusion, it is therefore necessary to envisage aircraft of 1,000 tons and more.

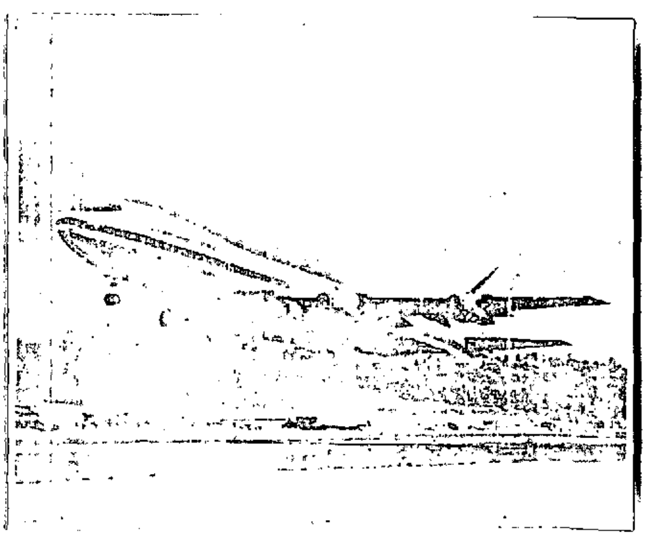

Figure 1

While this poses no problem of aerodynamics and flight

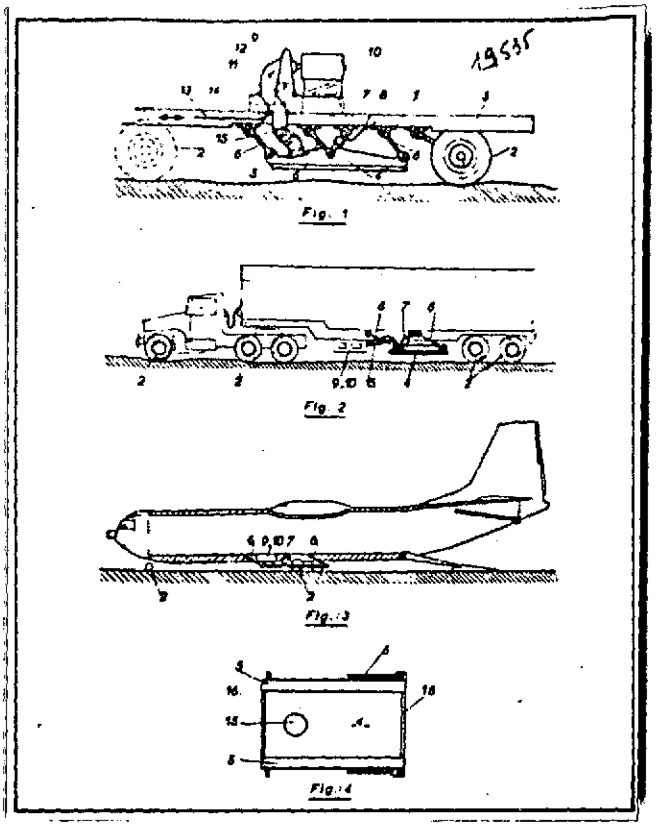

Figure 2

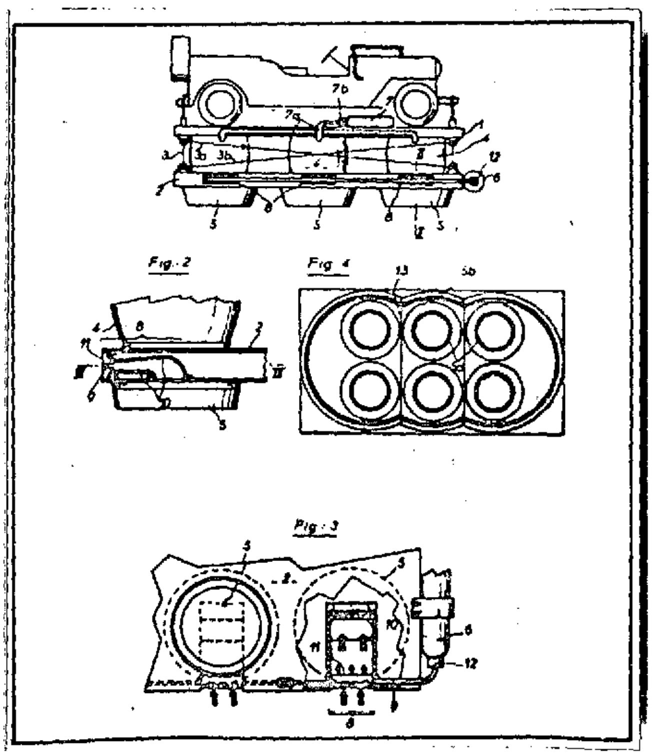

Figure 3

economics, it is necessary to determine the existence or non-existence of technological solutions.

It is no secret that one of the causes that limits the increase in tonnage of the conventional aircraft is, primarily, the landing gear. The B 747 (Fig. 1) clearly shows the considerable complexity of the multiple-wheel solutions. The same applies to the Lockheed C 5A. Today, however, we are very fortunate to have a new technique, the technique of landing on an air cushion.

We explained the basic principle of the system as early as 1962 (Fig. 2), and at that time we submitted several proposals for development unsuccessfully. A basic improvement was introduced in 1963 (Fig. 3) with the incorporation of shock-absorbing elements initially applied to the airdrop of heavy loads, but which little by little appeared to us to be the major element in an air-cushion landing system for aircraft.

The different sequences, (schematically represented in

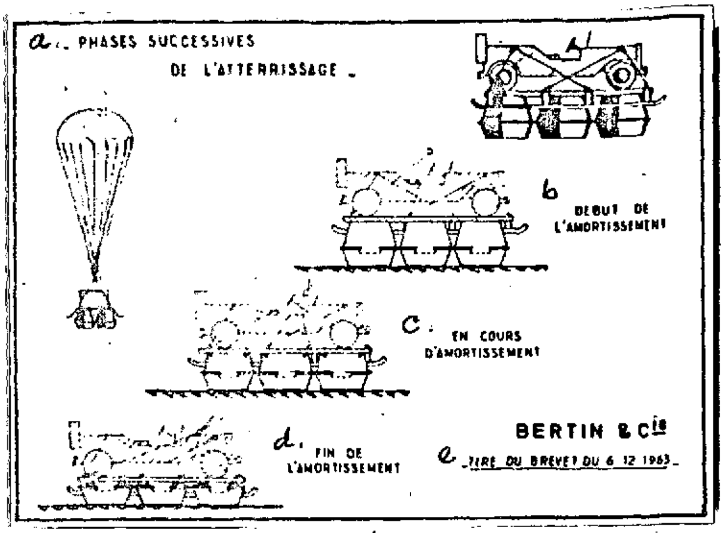

Figure 4

Key: (a) Successive landing phases; (b) Start of shock absorption; (c) Absorption process; (d) End of absorption; (e) Taken from patent of 12/6/1963.

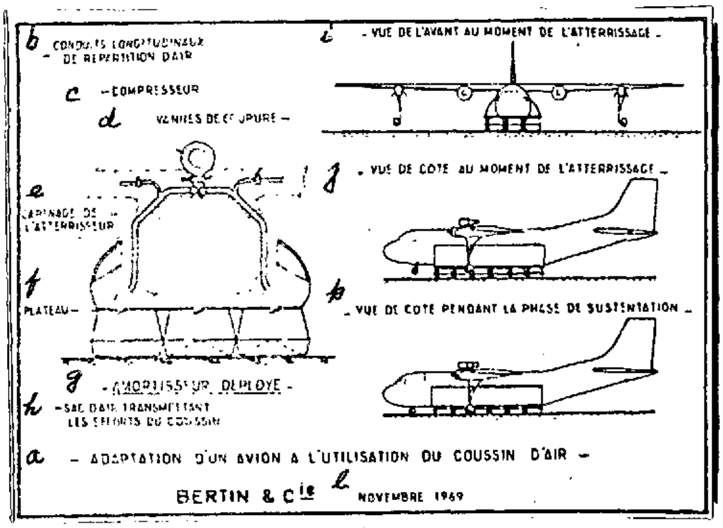

Figure 5

Key: (a) Aircraft adapted to use air cushion; (b) Longitudinal air-distribution conduits; (c) Compressor; (d) Cutoff valves; (e) Landing-gear fairing; (f) Plate; (g) Spread shock absorber; (h) Air bag transmitting cushion stresses; (i) Front view on landing; (j) Side view on landing; (k) Side view during lift phase; (l) November 1969.

Fig. 4) clearly show the part played by the intermediate capacities in the absorption of vertical velocities during the airdrop phase. Now, this can be transferred directly to landing (Fig. 5).

Installation on an aircraft does not create particularly difficult problems. The laws of similarity, which construction follows, generally provide a surface under the fuselage whose dimension in combina- /5
tion with the weight of the aircraft (Fig. 6) and a reasonable installed power (Fig. 7) makes it possible to produce ground effect under satisfactory conditions.

We must realize that all of the elements are available today to put this technique into practice. Its main interest probably lies both in its ability to take into account, in a very simple manner and with a light weight, the function of absorbing vertical velocity at the moment of

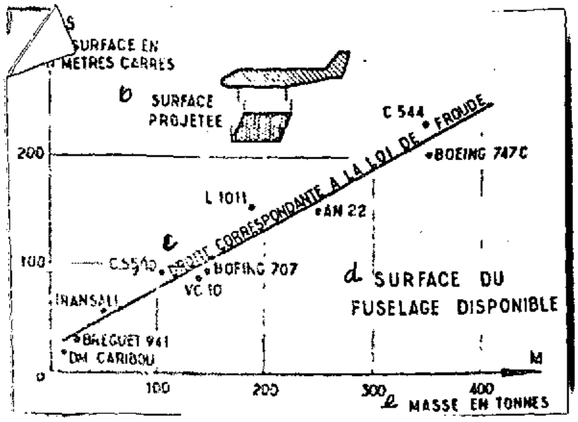

Figure 6

Key: (a) Surface in square meters; (b) Projected surface; (c) Line corresponding to Froude's law; (d) Available fuselage surface; (e) Weight in tons.

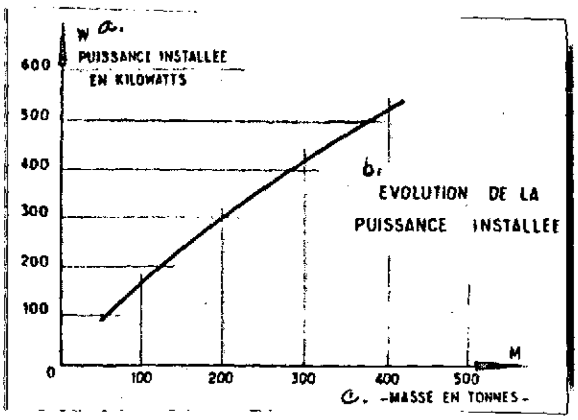

Figure 7

Key: (a) Installed power in kilowatts; (b) Development of installed power; (c) Weight in tons.

landing and a better distribution of stresses due to the air cushion. Be that as it may, the air-cushion landing gear makes it possible to be free of the scale effect by simplifying stuctures and to operate just as well on land and on water.

There is another problem that requires consideration: it is the problem of powerplants. If we adhere to the use of four engines, a unit power of 30,000 hp would be required. Now, there are no materials of this type. Current unit powers are limited to about 15,000 hp.

This is no drawback, however. The advances in turboengines in matter of reliability is such that there is nothing to prevent the simultaneous use of 8 to 12 engines located, naturally, on the wing span.

For those who might be surprised by this formula, suffice it to recall that that was the formula used in a certain number of seaplanes in the 1930's, particularly with the DoX (Fig. 8), whose performances were quite sensational for that period. Furthermore, the Americans themselves have induced development in this respect with the Boeing B 52's (eight jet engines).

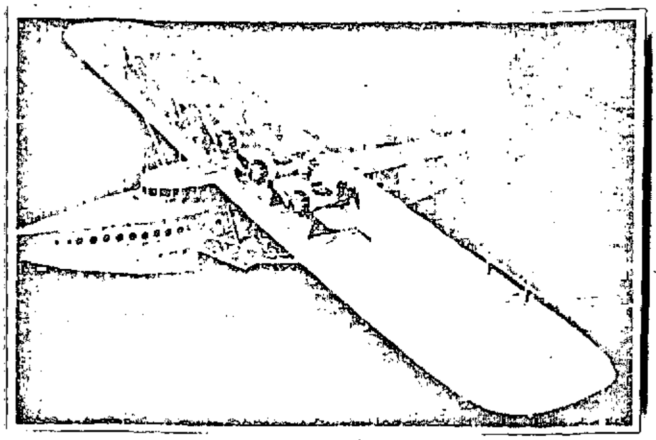

Figure 8

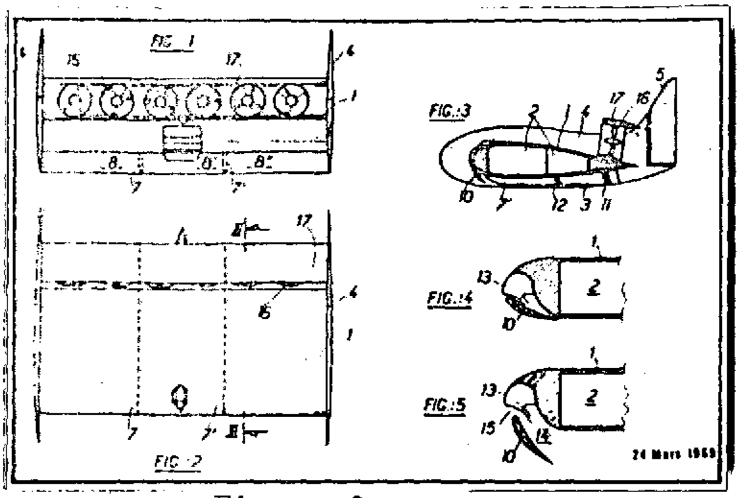

Figure 9

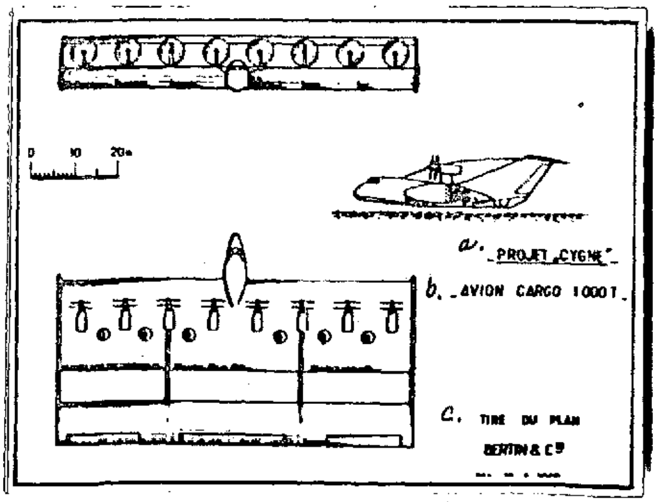

Figure 10

Key: (a) "Cygne" design; (b) 1000-ton cargo aircraft; (c) Taken from Bertin & Cie. drawing.

The last aspect to be considered is that of the structure. The answer is provided directly, in fact, by the choice of speed and the practical dimensions of the aircraft. Flying at about 200 knots actually means that straight, thick wings (15 to 20%), which are very easy to build, can be used.

By combining all of /6
these points of view we arrived at the "Cygne" [Swan] design, whose patents and diagrams date back to 1969 (Figs. 9, 10, 11 and 12). Today, the idea is in the offing, and American builders, Boeing and Lockheed recently disclosed large-tonnage aircraft designs. While the reason is similar, designs are entirely different (Figs. 13 and 14). The American projects actually use turbojets for propulsion. But these engines correspond to high Mach number flight, which involves a complex aerodynamic design at a high development cost.

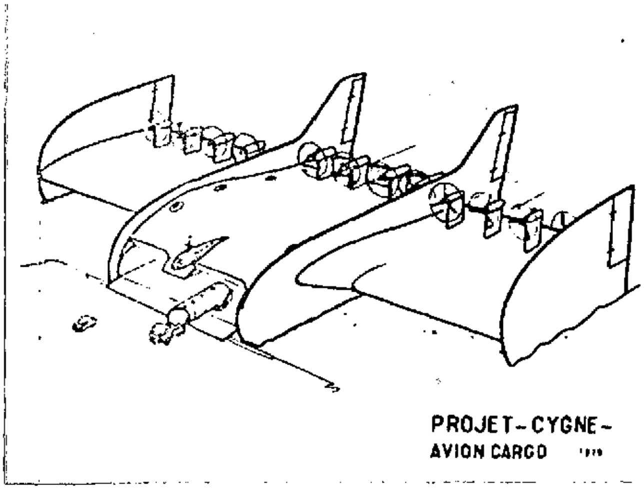

Figure 11
Key: (a) Cygne
(b) Cargo aircraft

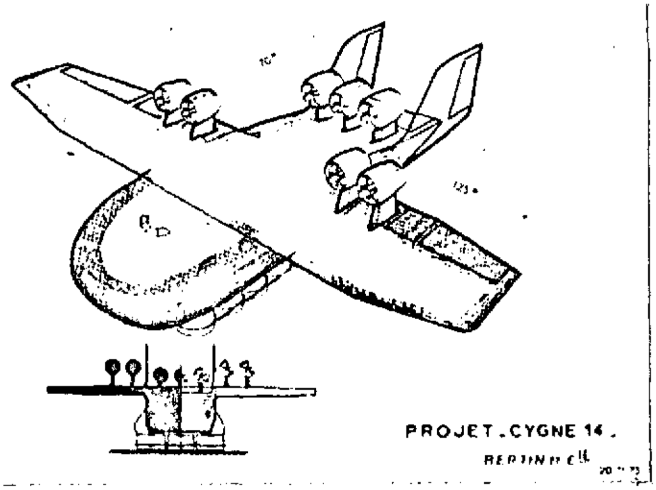

Figure 12
Key: (a) Cygne 14

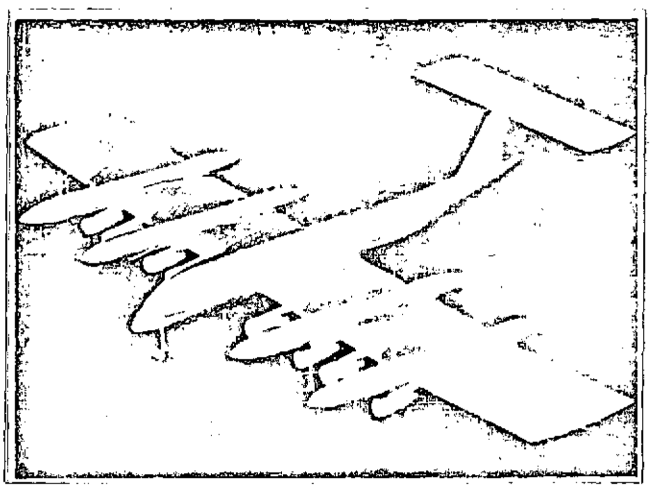

Figure 13

It is not, therefore, a case of carrying passengers but cargo which, as we have seen, does not involve such strict requirements. In our opinion, the aircraft should be built along the lines of a "giant truck" accepting a moderate speed which is, nevertheless, ten times greater than the speed of a ship. That is why we thought it was essential to revert to propeller propulsion and to less constraining takeoff conditions.

Several tables give the characteristics and performances of two preliminary designs (Cygne 10 and Cygne 14) that it is possible to design and build today at very low development costs.

Their economy, compared to those of the conventional aircraft, appears to be sufficiently attractive, particularly with intermediate

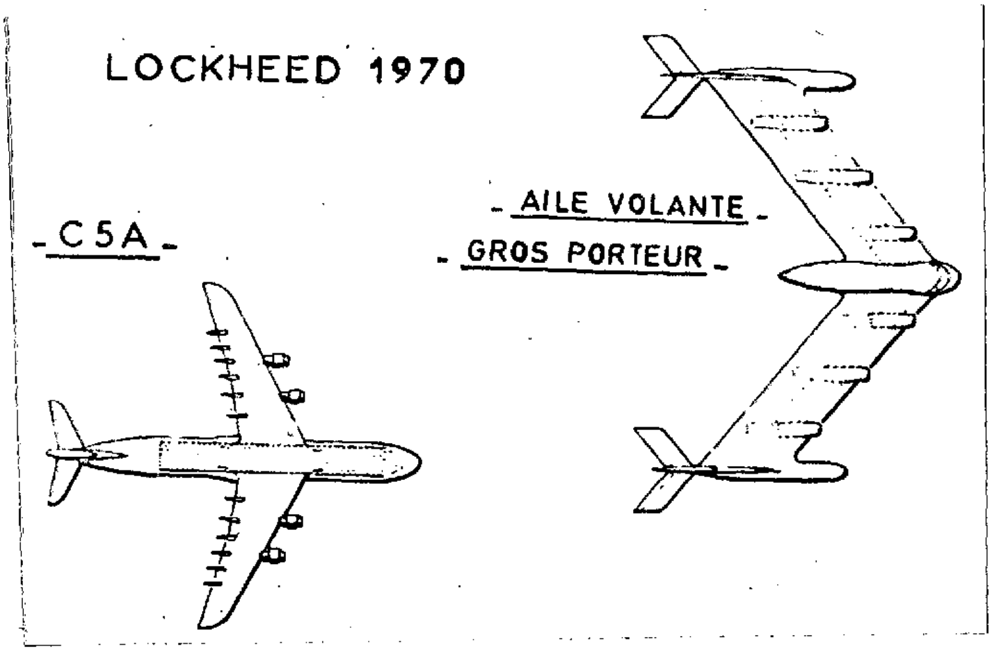

Figure 14

Key: (a) Flying wing
(b) Large carrier

refueling, so that it will not be impossible to enter shortly in the era of more than 1,000 tons, and even on a scale of 300 or 500 tons the formula considered might lead to very interesting aircraft.

DESIGN CHARACTERISTICS		
	Cygne 10	Cygne 14
Gross weight	1000 tons	1400 tons
Gross area	3860 m^2	4070 m^2
Span	108 m	115 m
Aspect ratio	3	3.25
Weight/area	259	334
Cushion with inflatable side keels (amp-ibian)		
Width	30 m	30 m
Length L	45 m	53 m
Aspect ratio	1.5	1.77
Area	1350 m^2	1590 m^2
Pressure P_c	740 kg/m^2	880 kg/m^2
P_c/L	16.4	16.6
Powerplants	12 x 10,000 hp or 8 x 15,000 hp	12 x 15,000 hp or 8 x 25,000 hp
Propellers	Ø 6.5 m	Ø 8 m or 10 m
Performances		
-- at full throttle z = 100 m	119 m/sec	134 m/sec
-- cruising at z = 25 m	114 m/sec 90,000 hp aerodynamic efficiency 20	133 m/sec 144,000 hp aerodynamic efficiency 20.6
Specific fuel consumption (engine advanced)	0.18 kg/hp/hr §	0.18 kg/hp/hr

§ General Electric LM 2500 announces a minimum of 0.17 kg/hp/hr. Rolls Royce is preparing a turboprop version based on an RB 211 gas generator, whose thermal efficiency will be at least the same.

DESIGN CHARACTERISTICS		
	Cygne 10	Cygne 14
Weight breakdown		
-- Structure Tons	300	330
-- Jackets	30	33
-- Powerplants	60	90
-- Equipment	60	80
Empty weight	450	533
Gross useful load	550	867
Empty weight/Total weight	45%	38%
Limited production price (10 aircraft)		
-- Powerplants	36 million francs	72 million francs
-- Structure	90 million francs	90 million francs
-- Electronics	16 million francs	16 million francs
-- Lift	10 million francs	20 million francs
-- Miscellaneous equip.	30 million francs	40 million francs
Purchase price	172 million francs	238 million francs

The technical assumptions for each of the aircraft are summarized in the following table:

Documentation Assumptions			
	Boeing 707	Boeing 747F	Cygne 14
Purchase price with spare parts	43 MF[1]	122 MF[1]	262 MF[1]
Maximum useful load	43.5 tons	106 tons	700 tons*
Compartment capacity 1 ft^3 g = 0.0284 m^3	280 m^3	950 m^3	5000 m^3 available
Cruising speed	425 knots	442 knots	260 knots
Cargo loading factor	0.8	0.8	0.8
Annual use H	3,000 hr	3,500 hr	3,500 hr
Development costs			
Annual capital expenditures MF[1]	5.10	14.55	29.2
Fixed charges MF[1]	2.80	4.74	7.0
Operating cost MF[1]	8.57	16.45	43.0
Total annual cost MF[1]	16.47	35.74	79.3

* In the case of the aircraft used for comparison purposes, the useful load, which is the authorized maximum, has not been adjusted as a function of the length of route.

[1] MF = million francs